AFAMRL-TR-81-27

(1) LEVEL II

#33

AD A108274

Aerospace Medical Research Laboratory

AIRCREW RESTRAINT AND MOBILITY TEST FIXTURE

A. B. McDonald
Douglas Aircraft Company
McDonnell Douglas Corporation
Long Beach, California 90846

DTIC
ELECTE
DEC 9 1981
S D
B

JULY 1981

Approved for public release; distribution unlimited.

AIR FORCE AEROSPACE MEDICAL RESEARCH LABORATORY
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AFB, OHIO 45433

81 12 09 012

NOTICES

TECHNICAL REVIEW AND APPROVAL

AFAMRL-TR-81-27

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Henning E. von Gierke

HENNING E. VON GIERKE
Director
Biodynamics and Bioengineering Division
Air Force Aerospace Medical Research Laboratory

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFAMRL-TR-81-27	2. GOVT ACCESSION NO. AD-A108 274	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AIRCREW RESTRAINT AND MOBILITY TEST FIXTURE		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) A. B. McDonald		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS McDonnell Douglas Corporation Douglas Aircraft Company 3855 Lakewood Boulevard Long Beach, California 90846		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62202F 7231-16-17
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Aerospace Medical Research Laboratory Aerospace Medical Division Air Force Systems Command Wright-Patterson Air Force Base, Ohio 45433		12. REPORT DATE July 1981
		13. NUMBER OF PAGES 35
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ejection Seat
Acceleration Protection
Restraint Devices

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Next generation combat aircraft with advanced aerodynamic and control features will have combat maneuver capability which will impose multiaxial accelerations on the aircrew. Advanced aircrew systems will be required for restraint, support, and mobility during these combat conditions. New concepts for these systems have been defined, but tests under representative dynamic conditions are necessary to evaluate the effectiveness of these concepts when implemented.

116400

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

BLOCK 20. Abstract (Cont'd)

In this program, a test fixture, which incorporates these new concepts is designed and fabricated. Concepts incorporated in the test fixture are aimed at providing the crewman with the restraint and mobility necessary for effective operation in high multiaxial acceleration conditions. A particular goal is for the restraint concepts to provide lateral support in a sustained lateral acceleration environment. The mobility concepts are specifically intended to permit the crewman to obtain aft visibility during sustained high-acceleration turns. The test fixture includes representative seat surfaces and flight controls. The seat surfaces can be set in a range of positions to simulate an articulating or reclined seat with a backrest angle of up to 65 degrees. The restraint features consist of an advanced strap-type system, side supports with inflatable bladders and seat cushions which conform to the contours of the crewman. Mobility features consist of a powered, pivoting headrest and a rotatable backrest. The fixture is designed to be installed in the AFAMRL centrifuge and impact test track facilities so that live subject evaluation tests can be conducted under high multiaxial acceleration conditions.

SUMMARY

The design and fabrication of a test fixture incorporating advanced aircrew restraint and mobility systems is the second phase of a program aimed at identifying aircrew systems designs and criteria for the next generation of Air Force combat aircraft. It is anticipated that combat operations in these future aircraft will involve maneuvers which will subject the aircrew to high multiaxial accelerations and that advanced systems will be required to restrain and protect the crewman and to ensure that he will be able to operate effectively in this environment.

Advanced design concepts were evaluated and selected in a previous study and the effort in this phase of the program was to incorporate these concepts in a test fixture which could be used to evaluate the concepts under representative dynamic conditions in the AFAMRL centrifuge and on the impact test track facilities.

The concepts incorporated in the test fixture are intended to provide restraint and support for the crewman during high multiaxial acceleration conditions and to facilitate the mobility required for surveillance and target tracking during high G_z acceleration. The restraint provisions consist of a basic strap-type system which is augmented by an arrangement of inflatable bladders which provide restraint and support for the torso and limbs and by the use of cushions which conform to the shape of the individual crewman. Mobility for external visibility is facilitated by a pivoting headrest and by a rotatable backrest. These allow the fully restrained crewman to twist around for aft visibility. The headrest is powered and capable of moving the head against forces due to high $+G_z$ accelerations.

The test fixture includes seat surfaces and flight controls which place the test subject in a representative setting in which to evaluate the effectiveness of the restraint and mobility concepts. The geometry of the seat surfaces is based on that of an articulating ejection seat and the surfaces can be articulated from an upright position to a fully reclined position in which the backrest angle is 65 degrees. The test fixture framework is configured to mount within the cab of the AFAMRL centrifuge.

The intended use of the test fixture is to permit evaluation of the restraint and mobility concepts under dynamic conditions. The fixture has been configured to facilitate the conduct of vision and flight control experiments which would provide quantitative data for comparison with current aircrew systems.

PREFACE

The work described in this report was performed under Air Force Contract F33615-79-C-0522 "Test and Evaluation of Aircrew Restraint and Mobility Systems." The Principal Investigator was A. Blair McDonald.

The Air Force Technical Monitor was Lt. Col. James H. Raddin, Jr. of the Biomechanical Protection Branch, Biodynamics and Bioengineering Division of the Air Force Aerospace Medical Research Laboratory.

TABLE OF CONTENTS

SECTION	PAGE
INTRODUCTION	5
REQUIREMENTS	7
DESCRIPTION	8
GENERAL	8
BASIC GEOMETRY	8
SEAT STRUCTURE	8
CONTROLS	12
RESTRAINT	12
MOBILITY PROVISIONS	17
INTERFACES	26
CONFIGURATION	26
SUBSYSTEM	26
SAFETY	27
STRUCTURAL INTEGRITY	27
SUBSYSTEM FAILURE ANALYSIS	27
SAFETY PROCEDURES	28
REFERENCES	31

LIST OF ILLUSTRATIONS

FIGURE		PAGE
1	RESTRAINT AND MOBILITY TEST FIXTURE	9
2	UPRIGHT SEAT GEOMETRY	10
3	FULLY RECLINED SEAT GEOMETRY	10
4	SEAT IN UPRIGHT CONFIGURATION	11
5	SEAT ARTICULATED TO FULLY RECLINED CONFIGURATION	11
6	MODIFIED PCU-15/P TORSO HARNESS	14
7	INFLATABLE BLADDER ARRANGEMENT	15
8	BLADDER INFLATION SYSTEM SCHEMATIC	16
9	PIVOTING HEADREST WITH ROTATING "CAGE"	19
10	HEADREST UPRIGHT	20
11	HEADREST PIVOTED AFT	20
12	MOBILITY - AFT VISIBILITY DEMONSTRATION	21
13	HEADREST AND BACKREST MOTION	23
14	POWERED HEADREST SYSTEM SCHEMATIC	24

LIST OF TABLES

TABLE		PAGE
1	DYNAMIC CONDITIONS FOR LIVE TESTING	7
2	INFLATABLE BLADDER RESTRAINT FAILURE ANALYSIS	29
3	CONTOUR CUSHION SYSTEM FAILURE ANALYSIS	29
4	PIVOTING HEADREST FAILURE ANALYSIS (CENTRIFUGE)	29
5	ROTATABLE BACKREST FAILURE ANALYSIS (CENTRIFUGE)	29
6	STRAP RESTRAINT SYSTEM FAILURE ANALYSIS (CENTRIFUGE)	30
7	STRAP RESTRAINT SYSTEM FAILURE ANALYSIS (IMPACT TRACK)	30

INTRODUCTION

The second phase of an ongoing AFAMRL program aimed at defining aircrew restraint and protection system concepts and aeromedical criteria for the next generation of Air Force combat aircraft is described. The effort in this phase of the program consisted of the design, development and fabrication of a test fixture incorporating advanced design concepts for aircrew restraint and mobility under high acceleration maneuver conditions. The concepts were defined in the first phase of the program (Reference 1) but were modified and developed during this phase. The test fixture is designed to be used for live subject evaluation of the proposed concepts in the AFAMRL centrifuge and impact test track facilities.

BACKGROUND

The need for advanced aircrew restraint and protection systems for future aircraft is based on the projection that technology advances in propulsion, aerodynamics and flight controls in these aircraft will result in maneuver and flight envelope capabilities which are significantly greater than those of current combat aircraft. These technology advances include innovations such as the High Acceleration Cockpit (HAC) and developments in aerodynamics and control techniques which utilize direct lift, direct side force and drag modulation. The introduction of these technology advances will result in a combat environment in which the crewman will be subjected to high multiaxial accelerations.

Present aircrew systems were not designed to provide restraint and protection in this severe environment and there is a need for advanced design approaches which will meet the anticipated requirements. In order to attain the full combat advantages of the advanced aircraft design it will be necessary to restrain and support the crewman in such a manner that he will be able to operate and perform effectively during the application of high accelerations.

APPROACH

A program was initiated with the long-term objective of providing the aircrew system technology and aeromedical design criteria necessary to support next generation aircraft programs.

Concept Study

The first phase of the program, which is described in Reference 1, consisted of a study to identify and define advanced design concepts and to evaluate them relative to the requirements for restraint, protection and escape for the projected maneuver and flight envelopes. During the study, a conceptual approach (based on an articulating ejection seat) was selected and a mock-up was constructed so that the critical restraint and support aspects of the concept could be evaluated. The innovative features included the provision of "body fixation" restraint and support by means of a system of inflatable bladders augmented by the use of a contour-forming seat cushion and the provision of mobility for external visibility through the introduction of a powered, rotatable backrest and headrest.

The mockup permitted evaluation of the proposed concepts under $\pm$ 1 G_z and $\pm$ 1 G_y acceleration conditions. The results of the evaluation indicated that further investigation under more representative dynamic acceleration conditions was warranted.

Test Fixture

The second phase of the program consisted of the design and fabrication of a test fixture which would permit the evaluation of the proposed concepts under simulated combat multiaxial acceleration conditions in the AFAMRL centrifuge and impact test track facilities.

Investigations carried out during the design of the test fixture indicated that aft visibility for external surveillance and target tracking could be improved by the introduction of a movable headrest which could be tilted aft. This resulted in the incorporation of a powered pivoting headrest in place of the previous powered rotating backrest and headrest features, although the capability for manual rotation of the backrest was retained for evaluation purposes. The test fixture allows evaluation of the restraint, support and mobility concepts with the seat in the upright or reclined configurations. Primary aircraft controls are represented and the side stick controller is operable so that testing in the centrifuge may include quantitative target tracking experiments.

REQUIREMENTS

The basic requirement for the program was to incorporate the aircrew restraint and mobility concepts in a test fixture which would be satisfactory for the conduct of live subject tests using the AFAMRL centrifuge and impact test facilities.

The primary specific requirements emphasized test safety and test fixture integrity for live subject testing. The acceleration loading conditions for the live subject testing are listed in Table 1.

TABLE 1. DYNAMIC CONDITIONS FOR LIVE TESTING

TEST FACILITY	CONDITIONS	ACCELERATION LIMITS
CENTRIFUGE	Vertical and Lateral Acceleration	G_z = + 10.5G to -3.5G combined with G_y = + 3G to -3G
	Vertical and Longitudinal Acceleration	G_z = + 10.5G to -3.5G combined with G_x = + 3G to -3G
IMPACT TEST TRACK	Vertical Acceleration	G_z = + 10G
	Lateral Acceleration	G_y = $\pm$ 8G (seat upright)
	Longitudinal Acceleration	G_x = -10G

DESCRIPTION

GENERAL

The test fixture, shown in Figure 1, includes all of the elements of the seat and the flight controls which are necessary for a comprehensive evaluation of the restraint and mobility concepts under dynamic conditions. The fixture framework provides structural support for the seat, controls and subsystem components and is configured to mount on the platform in the AFAMRL centrifuge cab. The simulated flight controls and portions of the seat are adjustable so that the test fixture can accommodate a range of 5 through 95 percentile male body sizes (Reference 2).

BASIC GEOMETRY

The seat design is based on that of an articulating ejection seat in which the crewman can be reclined to enhance his tolerance to high + G_z acceleration. The geometry of the seat surfaces, the location of the controls and the articulation techniques are derived from the articulating ejection seat configuration proposed for the HAC (Reference 3). The seat surfaces articulate to move the crewman from a normal upright position in which the backrest angle is 15 degrees, to a fully reclined position in which the backrest angle is 65 degrees. The geometry for the upright and fully reclined positions is shown in Figures 2 and 3, respectively. As can be seen from these figures, the crewman is reclined by forward and upward movement of the seat bucket. With this method of articulation the location of the flight controls is satisfactory for all positions from upright to fully reclined.

SEAT STRUCTURE

The basic seat structure consists of the seat bucket and a backrest which is divided into three segments. The lower backrest segment is hinged to the seat pan. The center and upper backrest segments are mounted on a central spine bolted to the lower backrest segment and pin-jointed between the center and upper backrest segments. The seat assembly is secured to the fixture frame by two bolts on either side of the seat bucket and by a pivot bolt at the upper end of the backrest spine. Six sets of bucket attachment holes are provided in the frame and these allow the seat surfaces to be secured in an upright position or with the backrest reclined at an angle of 25, 35, 45, 55 or 65 degrees. The backrest hinge, pin-joint and pivot attachment features allow the backrest to articulate as the seat bucket is moved. Figures 4 and 5 show a subject in the test fixture with the seat in the upright and fully reclined positions, respectively.

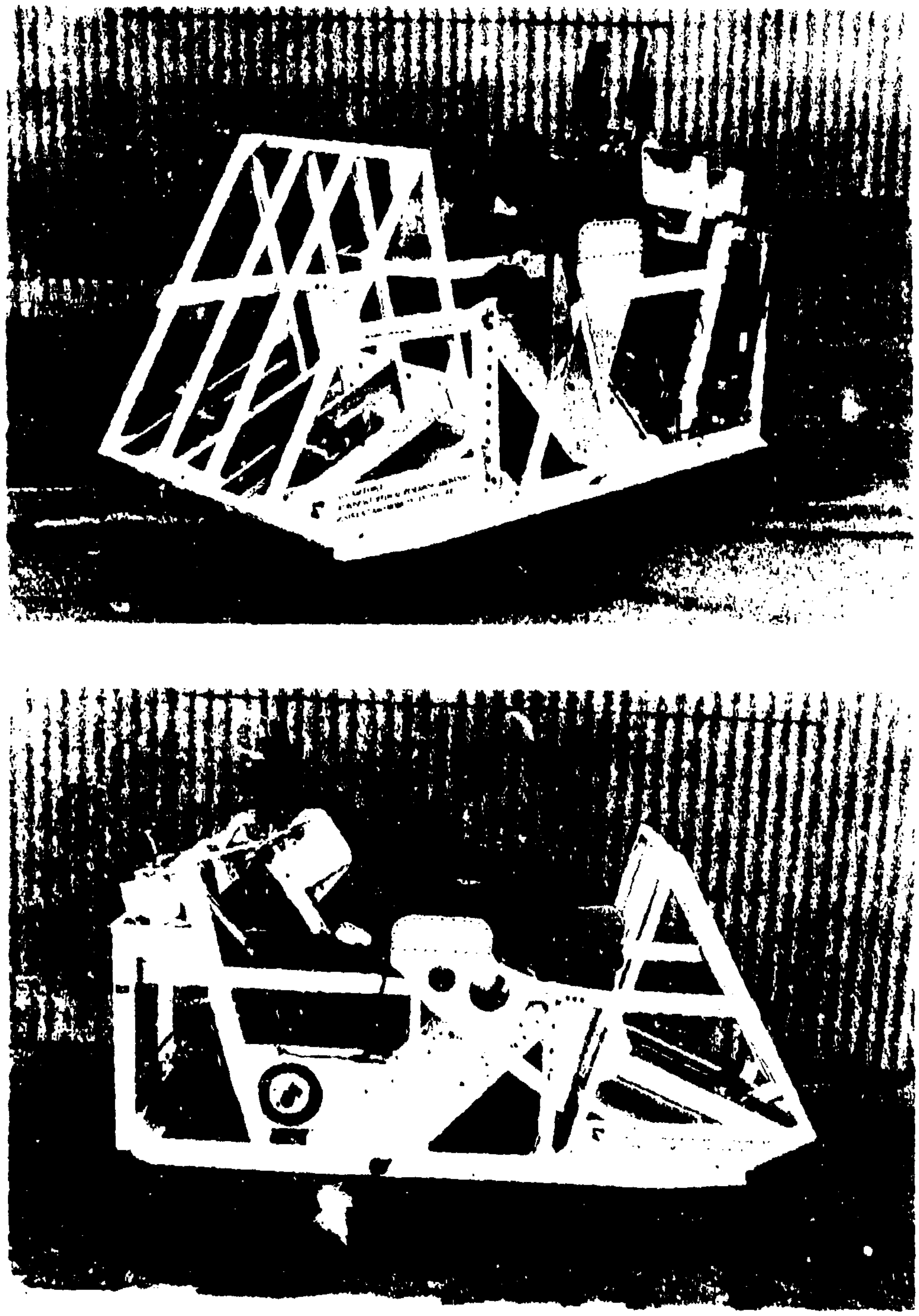


FIGURE 1. RESTRAINT AND MOBILITY TEST FIXTURE

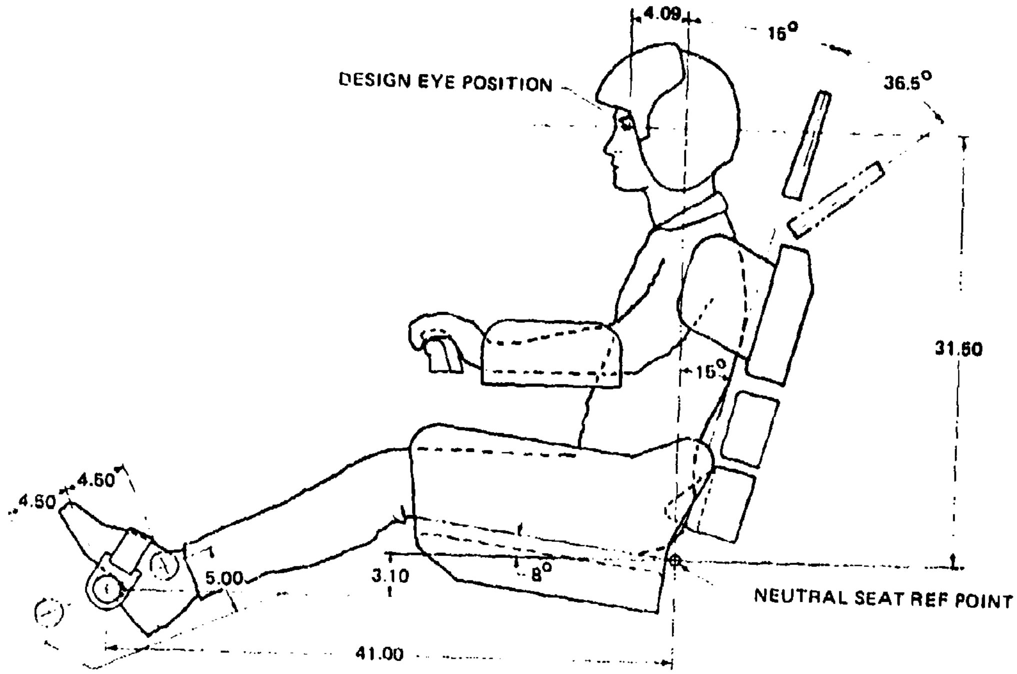


FIGURE 2. UPRIGHT SEAT GEOMETRY

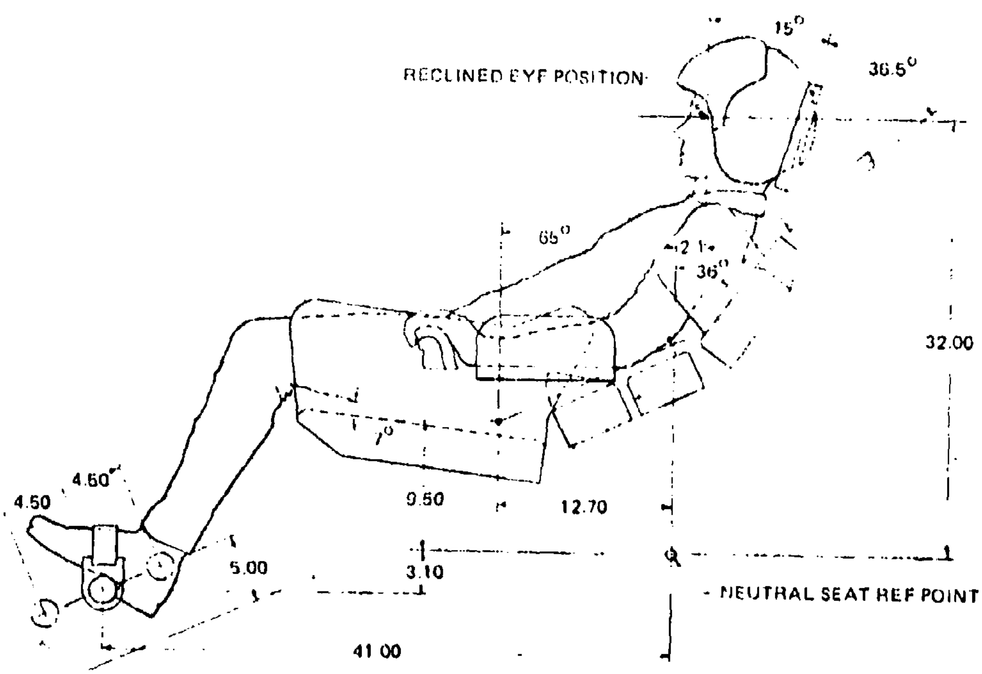


FIGURE 3. FULLY RECLINED SEAT GEOMETRY

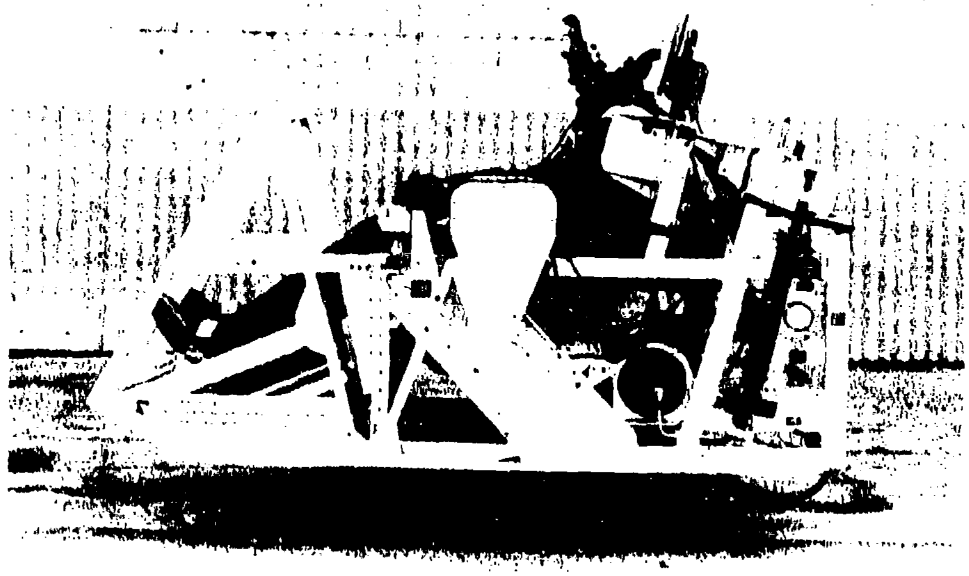


FIGURE 4. SEAT IN UPRIGHT CONFIGURATION

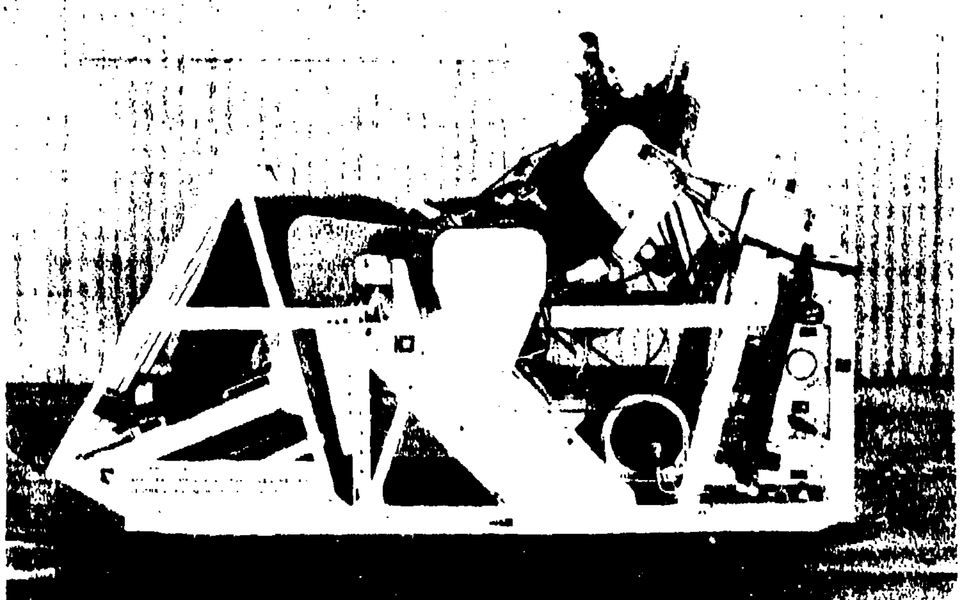


FIGURE 5. SEAT ARTICULATED TO FULLY RECLINED CONFIGURATION

CONTROLS

The fixture includes a side-stick controller and simulated rudder pedals and throttle. The side-stick controller is an operable unit of the isometric type and is part of a tracking experiment system used for quantitative evaluation testing in the AFAMRL centrifuge. The design and arrangement of the controls was previously shown in Figure 1. The rudder pedals are bolted to sloping rails and can be adjusted through a range of 9 inches in increments of one-half inch. The side-stick controller is mounted in the arm-rest support structure and the entire controller and arm-rest assembly can be adjusted on its sloping mounting surface. The throttle is fixed; however, the height of the throttle arm-rest can be adjusted by raising or lowering the arm-rest assembly on its sloping mounting surface.

Controls are also provided for operation of the seat subsystems and descriptions of these are included in the appropriate subsystem descriptions.

RESTRAINT

The restraint provisions consist of a basic strap-type system and a system to achieve "body fixation" under high multiaxial acceleration conditions. The strap system is more extensive than a conventional restraint system. "Body fixation" is attained by a system of support surfaces fitted with inflatable bladders and by cushions which conform to the contours of the crewman.

Strap Restraint System

The strap restraint system consists of a lap belt, shoulder and torso restraint straps and foot retention straps. The lap belt, shoulder and torso restraint straps are used in conjunction with a modified version of the standard Air Force PCU-15/P torso harness. Parachute risers attach to the parachute disconnects on the torso harness and are anchored to the test fixture framework with sufficient slack to allow full crewman mobility. Shoulder restraint is provided by dual straps from an inertia reel mounted on the aft surface of the upper backrest segment. The straps are routed over the backrest pivot bolt, pass around roller fittings on the parachute risers and are anchored to the fixture framework. The reel allows approximately 18 inches of forward motion. Torso restraint is provided by two straps from an inertia reel mounted on the aft surface of the center backrest segment. A roller fitting is attached to each side of the torso harness by means of quick-release fittings which are sewn onto the torso harness just below the chest strap attachments. The straps from the inertia reel pass around the roller fittings and are anchored to the center backrest segment. The shoulder and torso strap inertia reels and controls are identical to those used for shoulder strap retraction in current Air Force aircraft. The controls for the shoulder strap and torso strap reels are located on the right and left sides of the test fixture respectively and are readily accessible to the seat occupant.

The lap belt consists of two segments secured to the seat bucket and provided with adjusters and connector fittings. The connector fittings mate with adaptor fittings on a short center segment lap belt which is added to the PCU-15/P harness. Attachment of the lap belt to the torso harness will limit submarining under $-G_x$ acceleration when the crewman is reclined. The PCU-15/P torso harness, with the added center lap belt segment and torso strap attach fittings, is shown in Figure 6.

The foot retention straps are attached to the rudder pedals and are secured with Velcro tape. The straps assist the crewman to keep his feet on the rudder pedals and to resist upward motion of the lower legs during $-G_z$ acceleration.

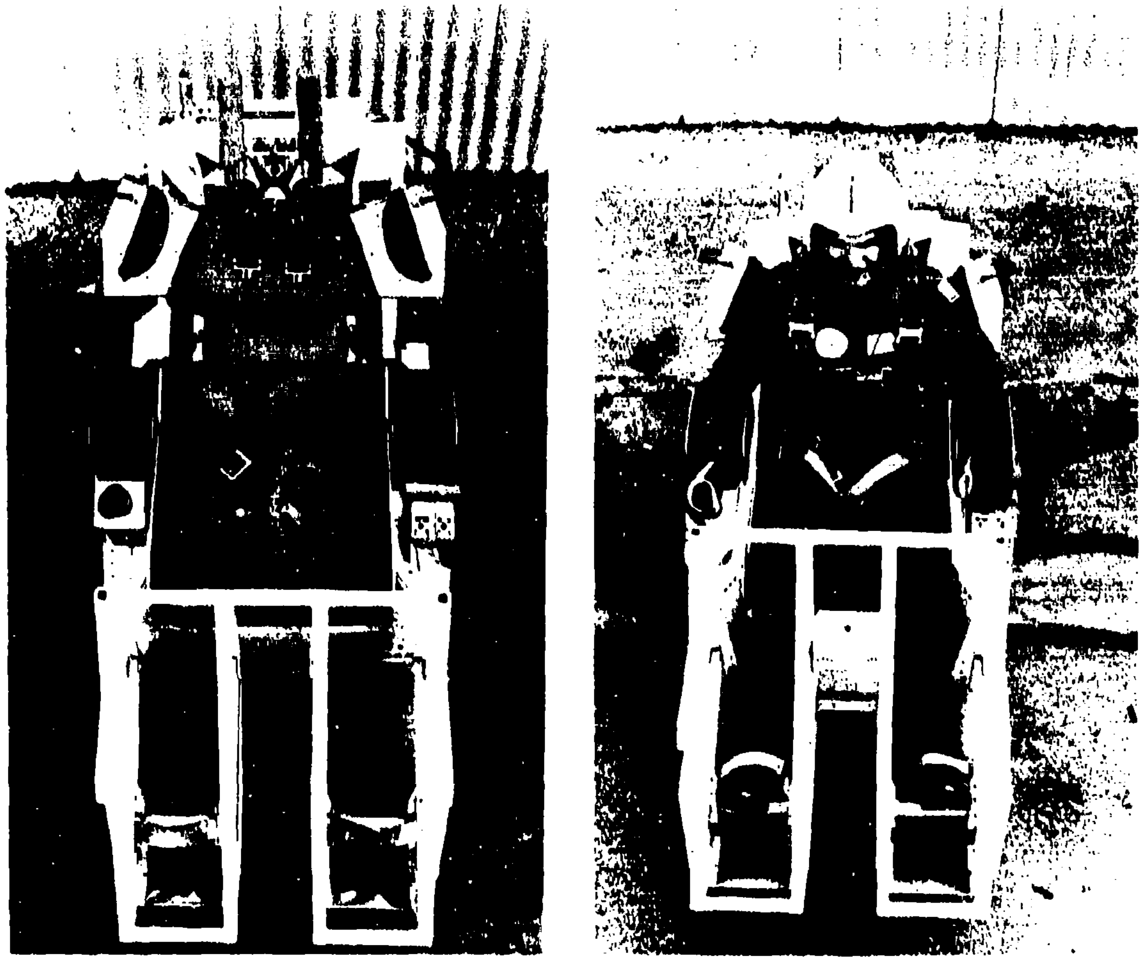
Inflatable Bladder System

In this system, a series of inflatable bladders, mounted on structural surfaces, is provided to support the torso and limbs and to prevent movement, particularly during application of sustained lateral accelerations. The bladders are installed on the inner surfaces of the seat pan, on forward projecting surfaces of the upper backrest segment and in troughs which form the arm-rests. The bladders are fabricated from neoprene coated nylon and are enclosed by stretch nylon-frothed neoprene covers which are secured to the support surfaces and control the final inflated shape.

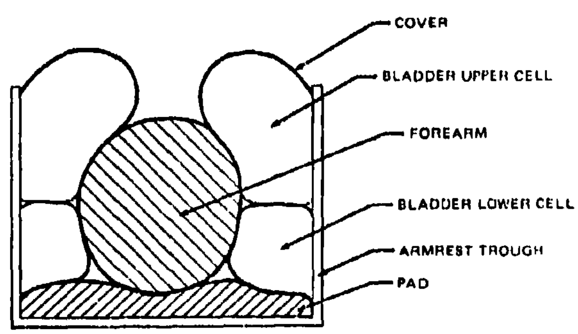
Figure 7 shows the arrangement of the bladders, the shape of the fully inflated bladders and a subject fully restrained in the test fixture. The seat pan has two bladders within a single cover on each side. The forward bladders support and restrain the thighs while the aft bladders restrict movement of the hips. The shoulder bladder supports can be adjusted to accommodate a range of shoulder widths. The arm-rest troughs are padded on their horizontal surfaces and have bladders on the vertical surfaces. Each arm-rest bladder, as illustrated in Figure 7, is a two-cell arrangement so that the bladders tend to enclose the arm and thereby provide restraint without the application of excessive force.

The bladders are inflated by compressed air with inflation and deflation being controlled by an electrical switch mounted ahead of the throttle grip. A schematic of the inflation system is shown in Figure 8. Compressed air from an external supply is required. The external supply is reduced in pressure to two to three p.s.i. and distributed to the inflatable bladders through a network of flexible hoses. An adjustable relief valve is included in the low pressure distribution system. The selector switch controls both an on-off valve and a two-way valve. With the switch selected to "INFLATE" the on-off valve is open and the two-way valve allows air to pass into the bladders. With the switch selected to "DEFLATE" the on-off valve is closed and the two-way valve allows any pressure in the bladders to vent to atmosphere. A master electrical switch on the left side of the fixture controls the power supply to all of the subsystems, including the bladder inflation system. When power is switched off, the air supply to the bladders is interrupted and the bladders are vented to atmosphere.

FIGURE 6. MODIFIED PCU-15/P TORSO HARNESS



(a) GENERAL ARRANGEMENT



(b) ARM RESTRAINT BLADDERS

FIGURE 7. INFLATABLE BLADDER ARRANGEMENT

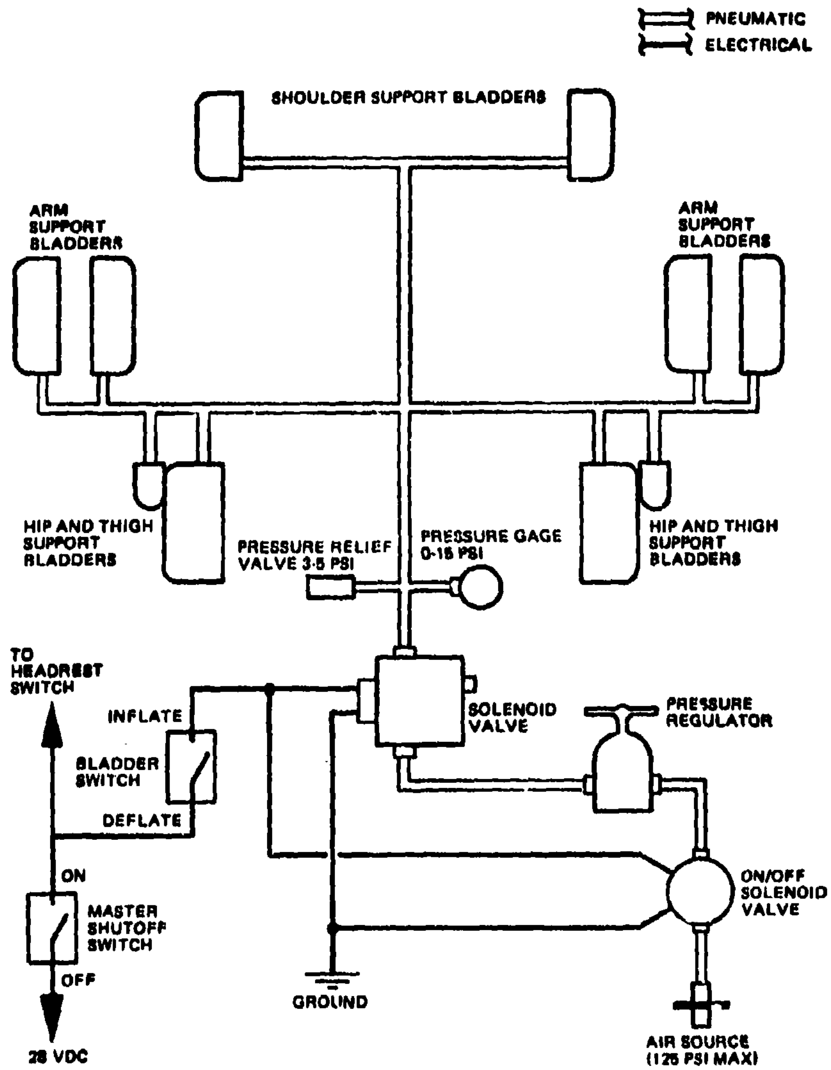


FIGURE 8. BLADDER INFLATION SYSTEM SCHEMATIC

Conforming Cushion System

Cushions which can be contoured to the shape of the individual occupant are installed on the seat pan and on each of the three backrest segments as shown previously in Figure 7.

In the contoured condition, the cushions tend to cradle the body and thereby provide support and prevent motion, particularly against lateral accelerations Also, during the contouring process, the seat cushion tends to fill the gap between the upper thighs and this should help to prevent submarining during $-G_x$ forces introduced by drag modulation. An inherent attribute of contoured cushions is that body pressure is spread evenly over the contact surfaces. This could have beneficial effects on comfort and may be significant during high $+G_z$ maneuvers when contact pressure is greatly increased. The cradling or "body fixation" effect of the contoured cushions is difficult to describe and must be experienced to be fully appreciated.

Each cushion consists of a bladder filled with small expanded polystyrene beads. The bladder material is frothed neoprene faced by stretch-nylon. The cushion bladders are connected by hoses to a pneumatic pump-vacuum unit which controls the operation of the cushions. To "contour" the cushions the seat occupant inflates the bladders slightly and then evacuates the bladders as he presses his body into the cushions. Evacuation causes the polystyrene beads to lock together in a rigid mass which conforms to the contours of the impressed shape. The conforming process can be repeated any time the occupant wishes to change position. The pump-vacuum unit for the cushions is mounted beneath the left arm-rest. The unit is battery-powered and the control switch, mounted on the unit, is accessible to the occupant.

MOBILITY PROVISIONS

The test fixture incorporates a powered pivoting headrest and a backrest design in which the center and upper backrest segments can be rotated. The objective is to enable the crewman to look around, particularly in the aft direction, for surveillance and target tracking during high $+G_z$ acceleration conditions. The headrest configuration is a new concept which was developed during the program. The development effort, rationale and design features are described in the following paragraphs.

Development

During the initial stages of the test fixture design, it was intended that the mobility concepts be those demonstrated in the previous program (Reference 1). These concepts consisted of the provision of a powered rotatable backrest and headrest. With this approach, the rotation was essentially lateral and further investigation indicated that the field of vision, particularly aft vision, could be improved if the crewman was able to tilt his head back in addition to rotating his head laterally.

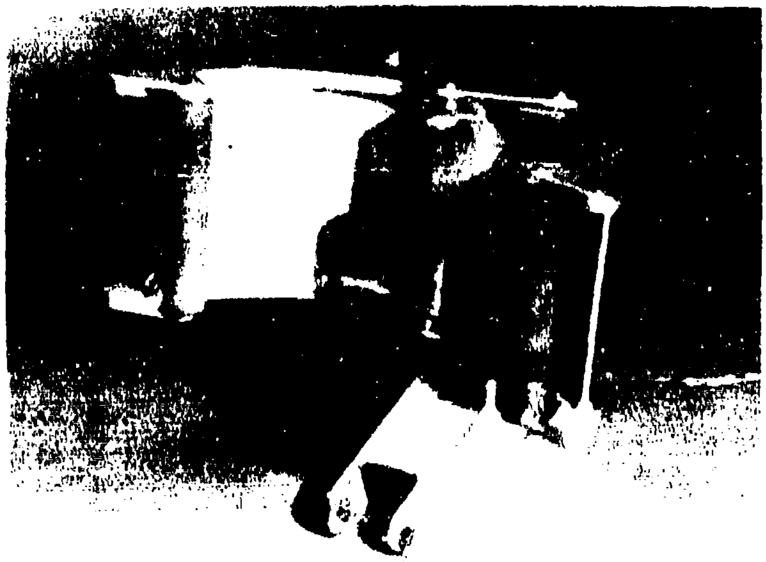
To evaluate this approach, a prototype of a new headrest was fabricated. This headrest was designed to pivot aft and had three rollers to "cage" the helmet. The rollers, as shown in Figure 9, were mounted on a frame which could rotate laterally on tracks. The pivoting motion was powered by an actuator while the lateral motion was accomplished by movement of the crewman's head.

Evaluation of this headrest design indicated that the lateral motion concept was unsatisfactory. One problem was that the head turning motion was found to be awkward and unnatural. A more serious problem was that it was relatively easy for the headrest to get out of position relative to the head. When this occurred the headrest became a source of interference and potential injury. Evaluation of this design led to a reappraisal of the mobility requirements. It was concluded that the primary requirements were to provide support for the head under high $+G_z$ acceleration and to assist the pilot to return his head from an aft vision position to the upright position, also during the application of high $+G_z$ acceleration. It was believed that these requirements could be met by a powered tilting headrest and that the provision of a headrest rotation feature was not warranted. It was also considered that the powered backrest rotation feature, which was part of the previous mobility system, may not be required. However, it was decided to include manual backrest rotation in the test fixture so that the effect of this capability could be evaluated in the centrifuge. The design which was developed to meet these requirements is described in the following paragraphs.

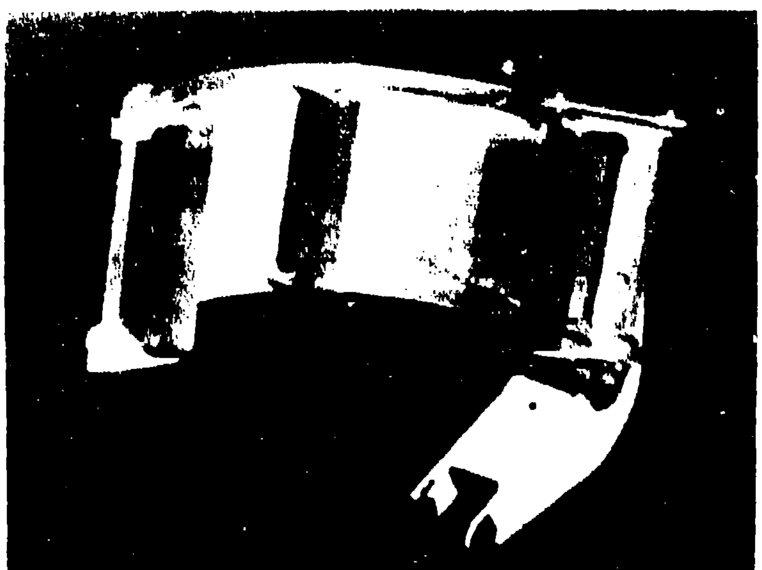
Headrest

In a conventional ejection seat, the crewman attains aft visiblity by leaning forward and twisting around so that he can look past the headrest. This type of motion is not practical during high acceleration, particularly when the crewman is reclined. In the concept developed to resolve this problem, the headrest pivots aft so that the crewman can obtain aft visibility by twisting his head around, no forward motion being required. Also, since the upper limit of acceleration at which head motion is possible is reported to be 4 G (Reference 4), the headrest is designed to support the head and to assist the crewman to return his head to the upright position. To achieve this capability, the headrest motion is powered by an actuator. The headrest upright angle is 15 degrees and the full aft angle is approximately 50 degrees. Motion is controlled by a switch mounted forward of the throttle grip and the headrest can be stopped at any point in its travel.

The headrest is shown in the upright position in Figure 10 and in the full aft position in Figure 11. Figure 12, shows a subject evaluating the aft visibility attainable with the headrest in the maximum pivot position.



(a) CAGE CENTERED



(b) CAGE ROTATED

FIGURE 9. PIVOTING HEADREST WITH ROTATING "CAGE"

FIGURE 10. HEADREST UPRIGHT

FIGURE 11. HEADREST PIVOTED AFT

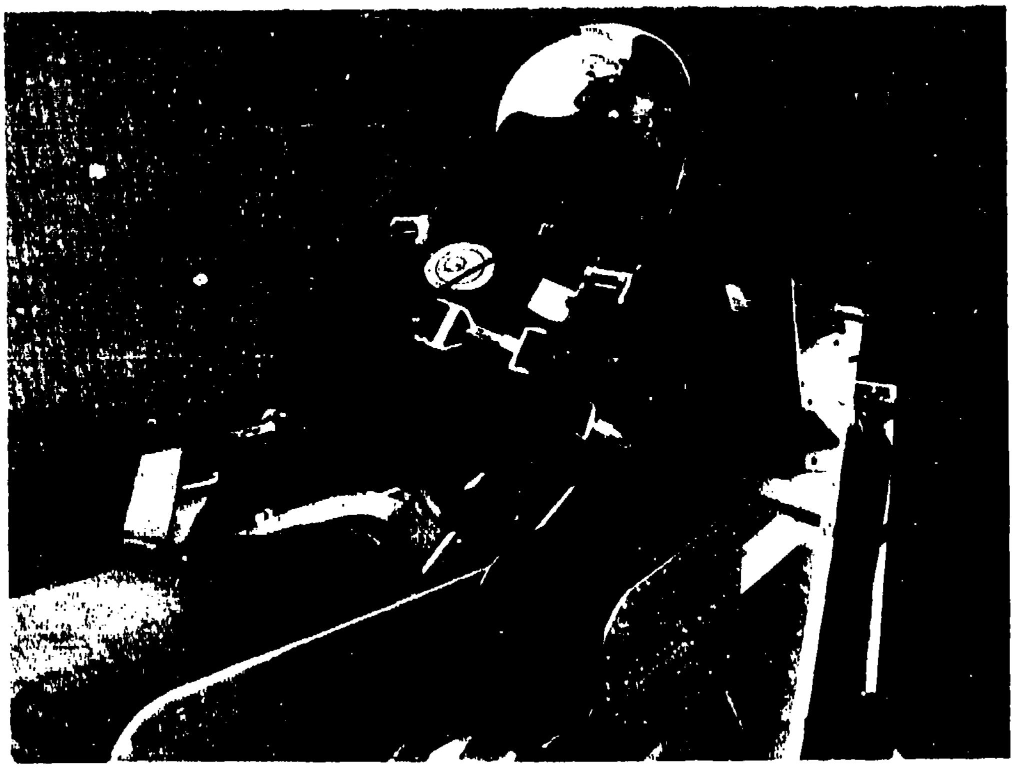


FIGURE 12. MOBILITY - AFT VISIBILITY DEMONSTRATION

When the pivoting headrest was initially proposed, a prototype was fabricated for evaluation. One adverse feature was that when the headrest was in the full pivot position the corners of the headrest interfered with the aft vision. In the final design, this problem was overcome by skewing the headrest hinges so that the tops of the headrest posts move inboard as the headrest pivots aft. This effect can be seen in Figure 13.

A second problem encountered was the existence of a scrubbing motion between the helmet and the headrest due to the offset between the head and headrest hinge points. Relative motion between the helmet and headrest was found to be approximately three inches. During powered motion, from full pivot to full upright, the scrubbing motion tended to drive the head downwards. If the helmet was held firmly against the headrest, simulating the effect of high $+G_z$ acceleration, the result of the downward force, for the unwary subject, was a severe pain in the neck. This problem was resolved by mounting the headrest pads on tracks so that they could move relative to the headrest structure during pivoting motion. When the headrest is in the upright position the pads are at the top of their travel and are held there by light bungee cords. When the headrest pivots aft, the pads are pulled progressively down the tracks by cables attached to the headrest pivot mechanism. The total travel is three inches so that the scrubbing action is eliminated. This feature has the additional benefit of reducing the size of the pivoted headrest and this helps to resolve the vision blockage problem discussed in the previous paragraphs. The effect of this feature on the headrest configuration is shown in Figures 10 and 11.

The headrest design is aimed specifically at meeting the requirements for aft visibility during high acceleration maneuver conditions. However, it appears that it would also be advantageous to have the capability of pivoting the headrest for improved vision during routine flight even when the crewman is seated in the upright position. As shown previously in Figures [illegible] and [illegible], the crewman's eye position moves aft approximately six inches in the transition from the upright to fully reclined position. It is conceivable that when a pivoting headrest is provided, it may be advantageous to allow the headrest to be pivoted forward of the 15-degree position so that the crewman could adjust the headrest position for [illegible] display visibility. In flight operations, the headrest would be in the upright position for take-off and landing, and would be automatically locked in the upright position for ejection.

In the test fixture the headrest is powered by a hydraulic actuator. The hydraulic system is mounted on the fixture and, as shown in the schematic in Figure 14, includes a reservoir, accumulator and pump. Operation of the system is controlled by electro-hydraulic valves. A momentary "on" switch is provided for operation by the test subject and electrical power is also controlled by the master "on-off" switch located on the left side of the fixture.

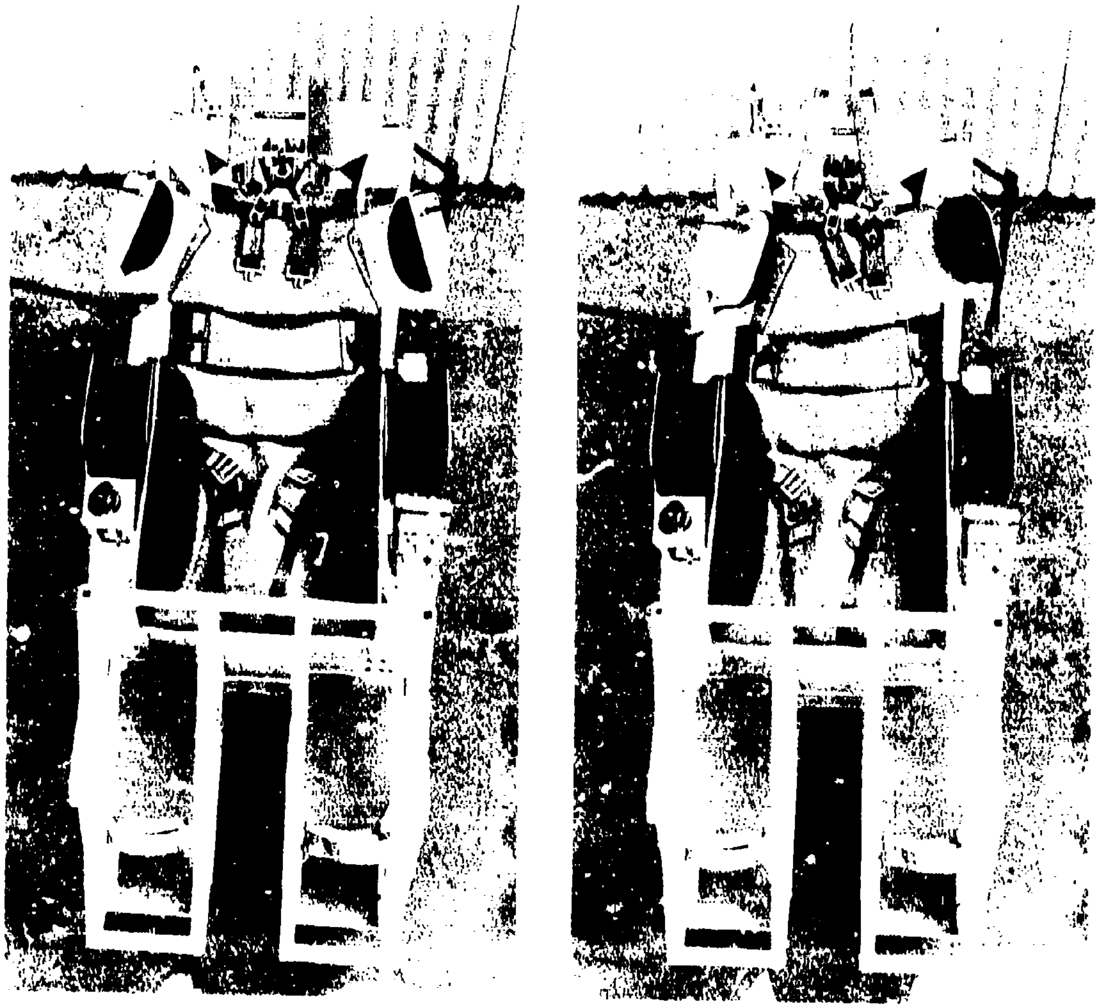


FIGURE 13. HEADREST AND BACKREST MOTION

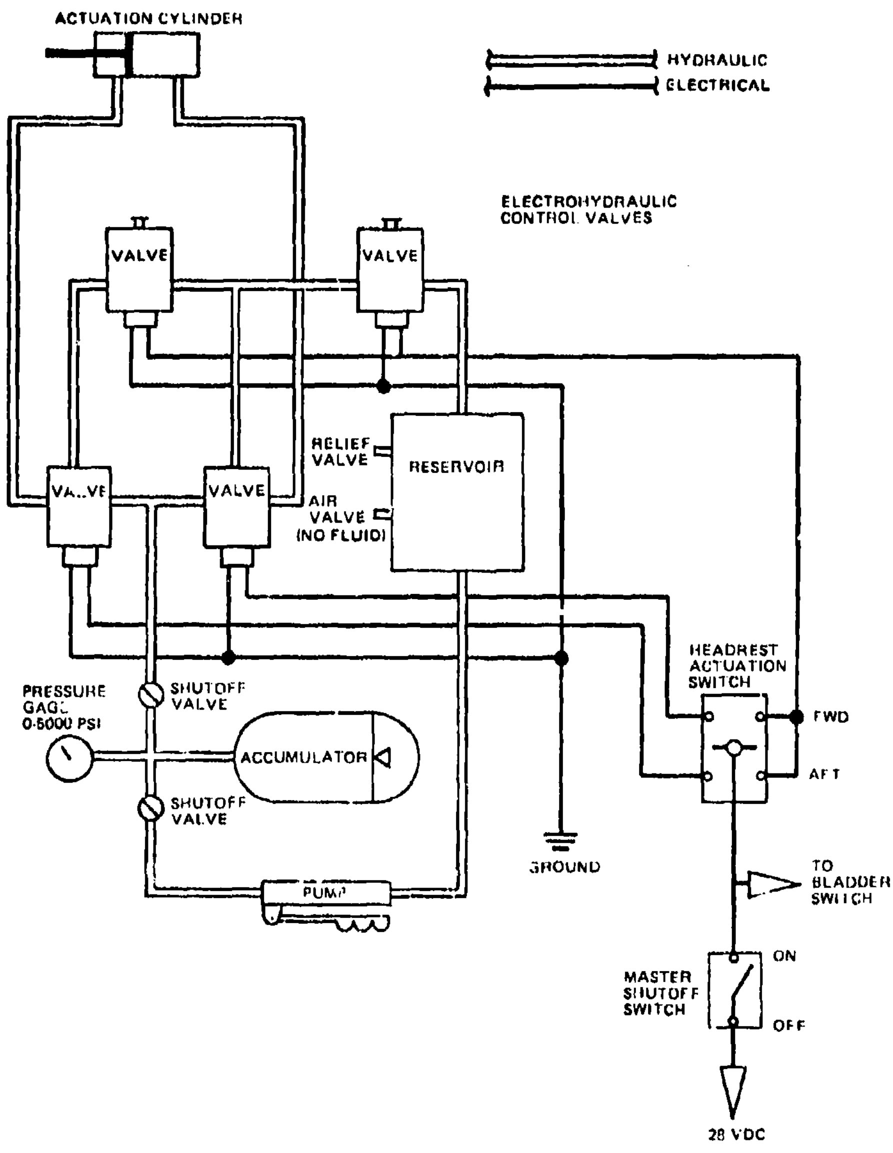


FIGURE 14. POWERED HEADREST SYSTEM SCHEMATIC

Rotatable Backrest

The mobility provisions in the test fixture include a rotatable backrest so that the value of this concept can be evaluated. The objective of the rotatable backrest is to allow the fully restrained crewman to twist his upper torso to facilitate aft and upward visibility.

When a crewman twists around to look aft, the degree of twist increases progressively from the waist to the shoulders. This is matched by the backrest rotation capability. The lower backrest segment is fixed, the center backrest segment can rotate ± 15 degrees and the upper backrest segment can rotate ± 30 degrees. Backrest rotation is illustrated in Figure 13.

The upper backrest segment can be locked in the neutral position when the seat is in the upright or fully reclined positions. When the locks are not engaged the backrest is free to rotate under pressure applied by the crewman's torso.

INTERFACES

CONFIGURATION

The test fixture is required to mount in the AFAMRL centrifuge and impact test track. The fixture configuration and mounting provisions were dictated by the requirements of the centrifuge installation since these were more restrictive than those of the impact test track. Specific interface features are:

- o The forward "instrument panel" portion of the fixture is detachable to facilitate installation in the cab.
- o The mounting flanges on the fixture base are spaced to match the cab platform support structure.
- o The forward portion of the fixture framework is configured to avoid interface with cab structure and to be compatible with the equipment and viewing requirements of the tracking experiments.
- o The aft portion of the fixture framework is below eye level so that it will not interfere with aft vision experiments.
- o Proximity to the cab entry hatch was an important factor in the placement of subsystem controls.

The mounting flanges on the base of the fixture can be used to secure the fixture to the experiment platform in the impact test track. The fixture mounts directly on the platform for G_x and G_y acceleration tests but an adaptor is required for tests with G_z acceleration.

SUBSYSTEMS

An external supply of compressed air is required for the inflatable bladder portion of the restraint system and electrical power is required for the inflatable bladder and powered headrest systems. The conforming cushion system uses a rechargeable battery and is self-contained as is the hydraulic portion of the powered headrest system. The electrical systems for the bladders and headrest are interconnected. External supply requirements are:

a. Compressed air, maximum pressure 125 p.s.i.
b. Electrical supply, 28 volts DC.

SAFETY

The intended use of the test fixture for dynamic tests with live subjects dictates the requirement for a high level of operational safety. The approach towards meeting this requirement is to ensure structural integrity and to configure the test fixture to enhance test safety and to facilitate the conduct of emergency procedures.

STRUCTURAL INTEGRITY

The structural integrity of the test fixture is verified by analysis and will be verified by test prior to the conduct of live subject tests. Analysis shows that the structure is satisfactory for stress levels which are three times the maximum stress levels which will be imposed in the live subject tests. The planned verification tests will be conducted using anthropomorphic dummies with test dynamic loads of 1.5 times those to be used in the live-subject tests.

STRESS ANALYSIS

A comprehensive stress analysis of the test fixture structure was made using a finite-element analysis program, called Computer Aided Structural Design (CASD), to identify the loads and deflections in each of the structural members for the centrifuge and impact track loading conditions. The analysis of the structure was conducted concurrently with the fabrication of the test fixture. This approach resulted in changes being required to the analysis as design and concept improvements were introduced. Also, changes had to be made to the structure when the analysis showed that some members did not satisfy the strength requirements. These were primarily in the fixture framework and involved the vertical members just forward of the seat bucket and the sloping members aft of the seat backrest. Design revisions were developed to increase the strength of these members. The stress analysis was then completed and the structural revisions were incorporated into the test fixture.

SUBSYSTEM FAILURE ANALYSIS

An analysis of subsystem failure modes and effects is presented in Tables 2 through 7. The analysis assumes that the tests will be conducted at the maximum acceleration levels which are tabulated in the Requirements Section, Page 7. The analysis also assumes certain test conditions. These are:

- Centrifuge - all of the subsystems will be operated and evaluated. It is assumed that the strap restraint system will be used in all tests but that other systems may not be in use as the purpose of the test may be to obtain comparative data.

- Impact Test Track - the headrest will be in the upright position and the backrest will be locked in the central position in all tests. It is also assumed that the strap restraint system will be used in all tests but that the inflatable bladder restraint system may not.

Centrifuge Tests

Examination of Tables 2 through 6 shows that the effect of a subsystem failure in the centrifuge tests will not have a significant effect on safety. This is primarily because the largest acceleration in the centrifuge tests is in the $+G_z$ axis and will tend to keep the subject firmly in the seat. In the other axes, the maximum accelerations are 3 to 3.5 G and it is assumed that the test subject would be able to prevent excessive motion if a restraint system failure occurred under these conditions. Table 4 shows a Category II hazard for inadvertent return of the headrest to the upright position prior to headrest actuation. This category was assigned because the head could be in any position and therefore the possibility of injury exists. A vertical plate separates the switches for headrest and bladder actuation to help prevent selection of headrest actuation when operation of the inflatable bladder systems is intended.

Impact Track Tests

Examination of Table 7 shows that there are conditions in which a failure of the strap restraint system is considered to be critical. These situations arise because of the relatively high forward and lateral accelerations, 10 and 8 G respectively, and because of the high rate of onset, approximately 250 G per second, imposed by the deceleration system. Although the integrity of the strap restraint system will be verified by test prior to the live-subject tests it may be prudent to secure a pad of impact absorbing material over the subject's legs and forward portion of the test fixture.

SAFETY PROCEDURES

The test fixture is designed to facilitate the safe and rapid removal of the subject in an emergency. A master electrical switch is located on the left side where it is readily accessible to test personnel. When the power is switched off, the headrest system is deactivated and the inflatable bladders are vented. This will avoid the danger of inadvertent headrest actuation during removal of the subject and will remove the possibility of interference due to the inflated bladders. To permit rapid removal of a subject, only quick-release connectors are used in the restraint system.

TABLE 2. INFLATABLE BLADDER RESTRAINT FAILURE ANALYSIS

FAILURE MODE	HAZARD* LEVEL	EFFECT OF FAILURE	COMMENTS
Failure to Inflate	I	No effect on safety - test would be discontinued.	Inflation would be selected prior to onset of high G conditions.
Failure to Deflate	I	No effect on safety - test would be discontinued.	Egress can be made with bladders fully inflated.
Loss of Pressure or Rupture	I	Restraint degraded under $-G_z$, $-G_x$ or $+G_y$ forces. Lack of bladder restraint should not cause injury.	o Restraint still provided by strap system. o Lateral motion limited by bladder supports.
Overinflation (Regulator Malfunction)	I	Minor discomfort due to bladder pressure.	o Overinflation pressure limited by relief valve.

TABLE 3. CONTOUR CUSHION SYSTEM FAILURE ANALYSIS

FAILURE MODE	HAZARD* LEVEL	EFFECT OF FAILURE	COMMENTS
Failure to Inflate or Deflate	I	No effect on safety - test would be discontinued.	Cushions would not be operated during high G conditions.
Loss of Vacuum	I	Body stability degraded - no effect on safety - test would be discontinued.	Adequate restraint provided by strap and bladder systems.
Overinflation	I	Minor discomfort due to increase in strap pressure.	Pressure capability of pump is limited.

TABLE 4. PIVOTING HEADREST FAILURE ANALYSIS (CENTRIFUGE)

FAILURE MODE	HAZARD* LEVEL	EFFECT OF FAILURE	COMMENTS
Failure to Pivot or Return	I	No effect on safety - test would be discontinued.	Headrest will not be operable in impact track tests.
Inadvertent Pivot	I	Sudden removal of head support during high + G_z or + G_x conditions would be disconcerting but should not cause injury.	Possibility of incorrect switch selection minimized if headrest switch is only throttle switch operated during high G conditions.
Inadvertent Return	II	Could conceivably cause injury if head is rotated and is not resting on headrest when actuation occurs.	o See comment above. o Protection provided by helmet. o Headrest is padded.
Pad Does Not Articulate	I	Could cause temporary discomfort under high + G_z or + G_x conditions due to downward scrubbing force on neck during return motion.	

TABLE 5. ROTATABLE BACKREST FAILURE ANALYSIS (CENTRIFUGE)

FAILURE MODE	HAZARD* LEVEL	EFFECT OF FAILURE	COMMENTS
Failure of Upper Backrest to Rotate or Return	I	No effect on safety - test would be discontinued.	Backrest will be locked except for visibility experiment in centrifuge.
Failure of Lower Backrest to Rotate or Return	I	Could cause minor discomfort.	Would only be noticeable at full rotation of upper backrest.

* Hazard Categories: I - Safe, II - Marginal, III - Critical, IV - Catastrophic

TABLE 6. STRAP RESTRAINT SYSTEM FAILURE ANALYSIS (CENTRIFUGE)

COMPONENT FAILURE	HAZARD* LEVEL	EFFECT OF FAILURE	COMMENTS
Lap Belt Segment	I	Reduced restraint on one side will allow pelvis movement under adverse acceleration forces. Forces are low and movement should not be excessive.	o Restraint still provided by shoulder and torso straps and remaining lap belt segment. o Lap belt integrity verified by test.
Shoulder Strap	I	Reduced restraint on one side will allow movement of the shoulder and head under adverse acceleration forces. Forces are low and motion should not be excessive.	o Restraint still provided by lap belt, torso straps, remaining shoulder strap and bladder supports. o Strap integrity verified by test.
Shoulder Strap Inertia Reel	I	Reduced torso restraint will allow movement of the upper torso and head under adverse acceleration forces. Forces are low and motion should not be excessive.	o Restraint still provided by lap belt and torso straps. o Reel integrity verified by test.
Torso Strap or Torso Inertia Reel	I	Lack of torso restraint straps should not allow motion which could cause injury.	o Basic restraint provided by lap belt, shoulder straps and bladder supports.
Foot Restraint Strap	I	Lack of restraint strap will allow upward motion under $-G_z$ forces. Force is low and motion should not be excessive.	o Straps are provided to reduce leg strain under $-G_z$ and are not required for restraint.

TABLE 7. STRAP RESTRAINT SYSTEM FAILURE ANALYSIS (IMPACT TRACK)

COMPONENT FAILURE	HAZARD* LEVEL	EFFECT OF FAILURE	COMMENTS
Lap Belt Segment	I II III	$+10\ G_z$ tests - no effect. $\pm 8\ G_y$ tests - body supported by seat sides but possibility of lateral rotation. $-10\ G_x$ tests - could allow submarining on one side. Possibility of minor injuries due to asymmetrical strap loads.	o Restraint still provided by shoulder and torso straps, remaining lap belt segment and bladder supports. o Seat will be upright in $-G_x$ tests. o Strap integrity verified by test.
Shoulder Strap	I III III	$+10\ G_z$ tests - no effect. $\pm 8\ G_y$ tests - could cause rotational motion of upper torso and head under adverse conditions. Excessive motion could result in injury. $-10\ G_x$ tests - will cause forward rotational motion of torso and head. Excessive motion could result in injury.	o Restraint still provided by lap belt, torso straps, remaining shoulder strap and bladder supports. o Seat will be upright in $-G_x$ tests. o Strap integrity verified by test.
Shoulder Strap Inertia Reel	I III III	$+10\ G_z$ tests - no effect. $\pm 8\ G_y$ tests - could cause rotational motion of upper torso and head. Excessive motion could result in injury. $-10\ G_x$ tests - will cause forward motion of upper torso and head. Excessive motion could result in injury.	o Restraint still provided by lap belt, torso straps and by bladder supports. o Seat will be upright in $-G_x$ tests. o Reel integrity verified by test.
Torso Strap or Torso Inertia Reel	I	All tests - lack of torso straps should not allow motion which could cause injury.	o Basic restraint provided by lap belt, shoulder straps and bladder supports.
Foot Restraint Strap	I	All tests - no effect.	o Straps are provided for centrifuge $-G_z$ tests.

* Hazard Categories: I - Safe, II - Marginal, III - Critical, IV - Catastrophic

REFERENCES

1. McDonald, A. B., July 1979, Advanced Design Aircrew Protective Restraint Systems, AFAMRL-TR-79-45, ADA-076 061, Aerospace Medical Research Laboratory, Wright-Patterson AFB, Ohio.

2. Human Engineering Design Criteria for Military Systems, Equipment and Facilities, MIL-STD-1472B.

3. Marti, V. M. and R. E. Mattes, April 1978, AFTI-15 Predesign and Preliminary Development of DFCS and HAC - Phase I, AFFDL-TR-79-3017 Part IV, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio.

4. Grumman Aerospace Corporation, October 1976, Crewman's Retention System for Protection Against High Speed Ejection up to 600 Knots., NADC-76119-40, ADA-036 898, Naval Air Development Center, Warminster, Pennsylvania.

U.S. GOVERNMENT PRINTING OFFICE: 1981—757-002/45